Landsat 7 Educational Activity for Grades 5-8

Finding Impact Craters with Landsat

♦ Activity Summary

Students consider the sudden release of a tremendous amount of kinetic energy when an extraterrestrial object strikes the Earth. They write about the effects that such a collision might have on the land, atmosphere, water, and living things.

Students then read descriptions of the actual effects of impact events and the evidence these leave behind. In small groups, they study satellite images that show possible evidence of impact events. They select one or two of these images to interpret for the class. In their interpretations, they explain how the image does or does not show evidence of an impact event.

To demonstrate their understanding of the role of impact events in shaping the Earth, students write a series of guidance questions for a field expedition to determine whether or not a given landform is an impact crater.

♦ Grade Level: 5-8

♦ Time

Two class periods (about 90 minutes) with pre-activity assignment and post-activity learning assessment as either homework or class work

♦ Goals for Student Learning

Students will:

→ **Describe the effects of extraterrestrial objects upon the Earth's topography, atmosphere, and living organisms**

→ **Describe the role of satellite technology in helping scientists to identify evidence of impact events**

→ **Describe why and how science is an ongoing process of discovery**

♦ National Standards

<u>Benchmarks for Science Literacy</u>

4C 6-8 #2. Some changes in the Earth's surface are abrupt (such as earthquakes and volcanic eruptions) while other changes happen very slowly (such as uplift and wearing down of mountains). The earth's surface is shaped in part by the motion of water and wind over very long times…

The activity can be linked to teaching this benchmark:
4E 6-8 #2. Most of what goes on in the universe…involves some form of energy being transformed into another. Energy in the form of heat is almost always one of the products of an energy transformation.

<u>National Science Education Standards</u>

Earth and Space Science Standard for Grades 5-8: The earth processes we see today…are similar to those that occurred in the past. Earth history is also influenced by occasional catastrophes, such as the impact of an asteroid or comet.

The activity can be linked to teaching this standard:
Transfer of Energy Standard for Grades 5-8: Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.
.

♦ Materials and Resources Provided

- Student worksheets

Student Worksheet for Step 1: *When an Extraterrestrial Object Hits the Earth*

Student Worksheet for Step 2: *Known Effects of Impact Events*
Student Worksheet for Step 4: *Describing Satellite Images of Possible Impact Craters*
Student Worksheet for Step 6: ***Questions You Would Ask on a Field Expedition to a Possible Impact Crater***

- Satellite images of landforms with pseudonyms for student use (Students may recognize some names and know already whether or not they're impact craters.)
  Aorounga (Aor)
  Elgygytgyn (Elg)
  Haughton (Hgh)
  Manicougan (Man)
  Mount St. Helens (Msh)
  Richat (Rch)
  Schooner (Sch)

- Diagrams of simple and complex impact structures
  http://cass.jsc.nasa.gov/expmoon/science/craterstructure.gif

- Rubric for student learning assessment

♦ Materials and Resources Needed from Teachers

Unless each student will have access to this activity online, teachers will need transparencies or paper to make student copies of the satellite images. (Please see Step 4.)

♦ About More Satellite Images

- A small selection of other images of Aorounga, Elgygytgyn, Haughton, and Manicougan can be found at the Earth Impact Database, Crater Image Archive:
  http://www.unb.ca/passc/ImpactDatabase/images.html

♦ Student Prerequisites

- Students should understand what a satellite is and should have a basic level of comfort with looking at the Earth from space.

- Students should understand that satellite images are not photographs. Researchers use very different kinds of technology to produce photographs and satellite images.

- Student should also understand that most satellite images use false colors to display information. The satellite images provided with this activity use false colors.

♦ Teacher Preparation

→ <u>Read and become familiar</u> with the Background section and any additional resources you think might help you. See "Relevant Resources" at the end of the section, *Background: Impact events are Key to Earth's History.*

→ <u>Read all the way through the lesson plan</u> to tailor the ideas to your class and to be comfortable with the sequence and information.

→ <u>Consider running a classroom lab</u> that gives students' experience at making craters of their own. Guidelines for such an activity can be found at:

Deep Impact: Making Impact Craters!
http://cass.jsc.nasa.gov/education/EPO/explore/craters.pdf

Although impacts of extraterrestrial objects onto the Earth's surface occur at hypervelocity (high speed) and involve much more kinetic energy <u>than</u> any impacts in a classroom lab <u>might do,</u> such a lab can be worthwhile. In this classroom lab, students make craters themselves and can notice how impacts of different-sized objects at different angles can produce differently shaped craters.

→ Make student copies of the satellite images on transparencies or paper.

Indicate the abbreviated name of the landform on each student copy of the image. (See "Materials and Resources Provided.)

If you use the full name, some students may recognize the landform as an impact crater or other landform such as a volcano known to them (Mount St. Helens).

→ Make student copies of the worksheets and readings:

Student Worksheet for Step 1: *When an Extraterrestrial Object Hits the Earth*
Student Worksheet for Step 2: *Known Effects of Impact Events*
Student Worksheet for Step 4: *Describing Satellite Images of Possible Impact Craters*
Student Worksheet for Step 6*: Questions You Would Ask on a Field Expedition to a Possible Impact Crater*

Please Note: It is recommended that teachers not distribute student readings before it is indicated to do so in the activity steps below. If students apply their own existing knowledge to a problem before doing the reading, the teacher will (1) have a better grasp of what the students know before they complete the activity; (2) give the students a chance to struggle with a problem and bring all their own resources to bear on it.

♦ Student Learning Assessment

Pre-activity assessment: Use student responses on Student Worksheet for Step 1: *When an Extraterrestrial Object Hits the Earth* to learn what ideas students already have about how impact events have shaped the Earth.

Post-activity assessment: Use *Student Learning Assessment for Step 6: Questions You Would Ask on a Field Expedition to a Possible Impact Crater*

A rubric for scoring the worksheets appears at the end of this activity

Comparing pre-activity and post-activity student responses to the worksheets for Steps 2 and 6 should provide a picture of what students have learned.

♦ Background: Impact events are Key to Earth's History.

Many people know that craters cover the surface of the moon. In fact, impact craters appear on all rocky (terrestrial) planets and many of their moons. The Earth has been shaped by these dramatic impact events no less than other planetary bodies have been, and one can see evidence on the Earth in terms of its geology, biology, and chemistry. The knowledge we can gain from studying impact craters is fundamental and interdisciplinary.

Science is an exploratory, dynamic process, and new ideas frequently come to light. Until about 40 years ago, impacts by extraterrestrial objects were not considered very significant by most geologists. Impact events are now recognized as more abundant, larger, older, more geologically complex, more economically important, and even more biologically significant than scientists had believed. Impact events have formed major ore deposits, generated large crustal disturbances, and produced huge volumes of igneous rock. We know that at least one major biological extinction event was probably triggered by the impact of an extraterrestrial object, and the coastline of Chesapeake Bay was partially shaped by an impact event. Impact events may have played a key role in the formation of the ocean basins and of the oceans themselves. Large impacts can drastically alter the chemical composition of the atmosphere.

Researchers have identified approximately 140 individual impact craters on Earth. These craters probably represent only about 25 percent of those to be found. Assuming an equal rate of impact around the globe, many more craters remain to be discovered, particularly in remote land regions of our planet and in the oceans.

NASA scientists currently study satellite images for evidence of impact events. Finding the evidence requires careful interpretation of satellite images. Wind and water have eroded away most of the evidence; various other geologic processes have concealed it; oceans and vegetation now cover much of the rest. Satellite observation technology enables us to see landforms that we can't see with our eyes alone. When impact craters are found in satellite images, interdisciplinary teams of scientists can go to the sites on the ground to learn more about them and how they have changed their surroundings.

These are some questions scientists are currently asking about impact events:

> How often do impacts occur? Does the rate of impacts vary over time? If so, does it vary regularly or randomly?
> Are asteroids or comets the more frequent impacting bodies?
> Have impact events caused more than one major biological extinction event?
> When will the next impact event take place? How big will it be, and how will it affect life?

♦ **Resources for Learning More**

About Impact Events – General

Craters! A Multi-Science Approach to Cratering and Impacts. William K. Hartmann with Joe Cain. 1995. (National Science Teachers Association) http://www.nsta.org/recommends/product.asp?id=12174

Educator's Guide to Impact Craters
http://www.solarviews.com/eng/edu/craters.htm

Meteors, Meteorites, and Impacts
http://seds.lpl.arizona.edu/nineplanets/nineplanets/meteorites.html

"What is a Bolide?" U.S. Geological Survey
http://woodshole.er.usgs.gov/epubs/bolide/introduction.html#simple_vs_complex_impact_craters

For Advanced Student and Teacher Background

Earth Impact Database. Natural Resources Canada
http://www.unb.ca/passc/ImpactDatabase/essay.html

Exploring Space, Exploring Earth: New Understanding of the Earth from Space Research
Paul Lowman. 2002. (Cambridge University Press)

Mars crater identification and aging with NASA Ames Research Center
http://clickworkers.arc.nasa.gov/top

Traces of Catastrophe: A Handbook of Shock-Metamorphic Effects in Terrestrial Meteorite Impact Structures. Bevan M. French
http://www.lpi.usra.edu/publications/books/CB-954/CB-954.intro.html
Available in print for just the cost of shipping, from:
Order Department, Lunar and Planetary Institute
3600 Bay Area Boulevard
Houston, TX 7058-1113, USA
Phone: 281-486-2172; Fax: 281-486-2186
E-mail: order@lpi.jsc.nasa.gov

About Risk of Impact

Asteroid and Comet Impact Hazards
http://impact.arc.nasa.gov/reports/spaceguard/index.html

Spacewatch. University of Arizona's Lunar and Planetary Laboratory
http://spacewatch.lpl.arizona.edu/

About the Chesapeake Bay Impact Crater

A Cosmic Tale: Mystery in Seven Parts. Landmark Communications, Inc.
http://www.pilotonline.com/special/meteor/

Investigating the Chesapeake Bay Impact Crater. U.S. Geological Survey (USGS)
http://geology.er.usgs.gov/eespteam/crater/

Finding Impact Craters with Landsat

≺ Lesson Plan ≻

Step 1 . Use students' interest in the highly dramatic, explosive to introduce the activity.

Show students an aerial photograph of Barringer Meteor Crater (also known as "Meteor Crater", and located in Arizona). Tell them this landform is about 1300 meters (0.8 mile) in diameter and 174 meters (570 ft) deep. Ask them, what do you think could have made a hole this big in the land? Discuss as a class.

Show an artist's rendering of an impact event. Two are provided.

1. "One Minute After the End of the Cretaceous" by William K. Hartmann ["Chicxulub #3 of 5 – 100 dpi.jpg"]

   Please be aware that anyone reproducing this painting for uses <u>other than</u> this classroom activity, "Finding Impact Craters with Landsat" must contact William K. Hartmann for his permission, at: <hartmann@psi.edu> or by using information at this URL: http://www.lpi.usra.edu/publications/books/CB-954/CB-954.intro.html

2. Impact Painting by Don Davis (Use hotlink or go to: < http://www.donaldedavis.com/PARTS/K-TNASA.jpg >

Tell students that many objects much smaller than a planet orbit the Sun, and sometimes the Earth's path crosses theirs. When that happens, there is an impact event of enormous force, with profound effects on rocks and soil, atmosphere, water, and living things.

Ask students to imagine hitting a dust particle or a fleck of paint in the air with their finger. They will understand that such a collision would not leave any lasting mark. Tell them that NASA engineers working on the Space Shuttle have found that even tiny flakes of paint floating in space (from earlier missions) can make craters one centimeter in diameter in Space Shuttle windows when they hit them, because of the speed of impact. Emphasize that there is a lot of energy in an object traveling fast. It has been calculated that the energy required to produce the Barringer crater was equivalent to the explosion of 15 million tonnes of TNT.

Have a discussion about what students may already know about impact events. Ask students if any of them have visited Barringer Meteor Crater. Students who have done so can describe their experience.

<u>Do the following either in the classroom or as homework the night before you wish to conduct the bulk of the lesson</u>:
Distribute the Student Worksheet for Step 1, "When an Extraterrestrial Object Hits the Earth".

On the worksheet, students read a short description of what happens during an impact event. Based on that reading and on their existing knowledge, they describe the effects such an event might have on the land, air, and living things, and evidence of these effects that might remain for thousands or millions of years.

In the classroom:

Step 2. Distribute Student Reading for Step 2: *Known Effects of Impact Events*, and have students read quietly alone or aloud together.

Step 3. Show either of the following, both of which are provided with this activity:
(a) the movie, "Iturralde Movie"
<u>or</u>
(b) the series of three still images from the movie, "Iturralde Stills", which is provided with this activity.
Explain to students that the movie is made of Landsat images of a location in Bolivia, made of the same data but displayed in different ways by NASA scientists as the movie progresses. The movie and the series of still images taken from it show very clearly how satellite technology helps us see landforms hidden in the Earth's surface that we cannot see with our eyes alone.

Step 4. Organize students in small groups (of three to five students). Distribute the following:

(1) One set of seven satellite images to each group

(2) One copy for each student of the Student Worksheet Sheet for Step 4*: Describing Satellite Images of Possible Impact Craters*

Given what students know about the evidence left by impacts, ask student groups to determine whether or not the landforms in all seven of the images <u>appear to be</u> impact craters.

Guidance questions are provided on the Student Worksheet.

<u>Monitor the student groups</u> as they discuss their analyses of the satellite images.

1. Make sure students understand that they should come to agreement as a group about their satellite images based on their analysis of the evidence in the images.

2. The Student Worksheet provides instructions about sharing their thoughts about the evidence before coming to agreement as a group. As groups discuss their analyses of the images, make sure they are discussing the evidence constructively with each other.

3. If students do not follow these instructions in the worksheet, direct them to choose one or two of the satellite images they find most interesting to interpret for the class, and to designate a spokesperson for the group.

Step 5. Have each spokesperson interpret the group's images. Make sure that all of the images in the set provided are covered in the class discussion.

Whether or not students believe each image shows an impact crater, their spokesperson must explain their group's thinking clearly and convincingly.

For positive identifications of the landforms as needed, use the *Teacher Reference for Step 5: The Landforms Identified*.

Either in the classroom or as homework:

Step 6. Distribute Student Worksheet for Step 6: *Questions You Would Ask on a Field Expedition to a Possible Impact Crater*

Ask students to write a set of questions for researchers going on a field expedition to an unidentified landform. The questions should serve well as guidance to determine whether or not the landform could be positively identified as an impact crater.

Landsat 7 Educational Activity Date: ___________________________
Finding Impact Craters with Landsat
Student Name: ___________________________________ Class Period: ______________________

Student Worksheet for Step 1:
When an Extraterrestrial Object Hits the Earth

You wouldn't hear it coming. A 100-ton extraterrestrial object hits the Earth at hypervelocity, more than 11 kilometers per second, and sometimes as fast as 20-25 km/sec. (Smaller objects slow down or are destroyed because of air resistance.) That's faster than sound (about 300 m/sec).

The object comes to a stop in about one hundredth of a second.

1. There is a rapid release of a tremendous amount of kinetic energy. What would be the effect of that rapid release of energy on the solid earth, the air, and living things? What forms might that energy take, and where might it go? Respond here:

Effects on rocks and soil: ____

____

____

Effects on the shape of the land (topography): ____

____

____

Effects on the air: ____

____

____

Effects on living things: ____

____

____

2. The energy release creates a shockwave stronger than any material it hits. What could be the effects of that shockwave on the rocks and soil, and on large bodies of water? Respond here:

____

____

3. What would be the effects of impact on the object itself? Would it remain intact (in one piece)? Respond here:

____

____

Landsat 7 Educational Activity | Date: ____________________
Finding Impact Craters with Landsat

Student Name: ______________________________ Class Period: ______________

Student Reading for Step 2:
Known Effects of Impact Events

When an object from space hits the Earth…

- There's a huge explosion.

- The impact makes a big hole or crater with a raised rim and *sometimes* a central peak.

  The hole is many times larger than the impacting object.

- There is a rapid release of a tremendous amount of kinetic energy as the object comes to a stop in about one hundredth of a second.

- The impact releases extreme heat. Usually, the object itself is vaporized. Sometimes it melts completely and mixes with melted rocks at the site.

- If the impact occurs in water, a whole column of water is vaporized.

- The impact also produces a super-hot blastwave – a shockwave – that radiates rapidly outward from the impact point through the target rocks at velocities of a few kilometers per second.

  The shockwave is stronger than any material on Earth. It deforms rock in ways that are characteristic of an impact event. No other event on Earth deforms rock in these ways.

- Tiny glass droplets can form during the rapid cooling of molten rock that splashes into the atmosphere.

- Large impacts also crush, shatter, and/or fracture the target rocks extensively beneath and around the crater. See diagram at: http://cass.jsc.nasa.gov/expmoon/science/craterstructure.gif

- Hot debris is ejected from the target area, and falls in the area surrounding the crater. Close to the crater, the ejecta typically form a thick, continuous layer. At larger distances, the ejecta may occur as discontinuous lumps of material.

- Large impact events can blow out a hole in the atmosphere above the impact site, permitting some impact materials to be dispersed globally by the impact fireball, which rises above the atmosphere. The resulting extensive dusk and smoke clouds can cause darkness lasting for a year.

- Special carbon molecules called Buckminsterfullerenes or (Bucky-balls, after Buckminster Fuller) can travel to the Earth in the impactor. They can hold special gases called "noble" gases that are indicators of extraterrestrial origin.

- Large impacts can trigger earthquakes and initiate volcanic eruptions.

- The heat ignites fires, and they may rage across a large region.

- Impact events can alter the chemical composition of the atmosphere. The extreme heat can generate large amounts of nitrogen oxides (NOx). NOx is easily transformed into nitric acid, resulting in acid rain.

More About …

More About Impact Events in General

Impact craters are geologic structures formed when a large meteoroid, asteroid or comet smashes into a planet or a satellite.

A very large number of meteoroids enter the Earth's atmosphere each day, amounting to more than a hundred tons of material. They are almost all very small, just a few milligrams each. Only the largest ones ever reach the surface. The average meteoroid enters the atmosphere at between 10 and 70 km/sec. All but the very largest are quickly decelerated to a few hundred km/hour by atmospheric friction, and they hit the Earth's surface with very little fanfare. However meteoroids larger than a few hundred tons are slowed very little; only these large (and fortunately rare) ones make craters.

All the inner bodies in our solar system have been heavily bombarded by meteoroids throughout their history. The surfaces of the Moon, Mars and Mercury, where other geologic processes stopped millions of years ago, record this bombardment clearly. On the Earth, however, which has been even more heavily impacted than the Moon, craters are continually erased by erosion and redeposition as well as by volcanic resurfacing and tectonic activity. Thus only about 120 terrestrial impact craters have been recognized, the majority in geologically stable areas of North America, Europe and Australia. Spacecraft imagery has helped to identify structures in more remote locations that can be explored for positive identification.

More About the Energy Released by Impact

Energies of impact are almost incomprehensibly large. They come chiefly from the kinetic energy of the impacting object. An object only a few meters across carries the kinetic energy of an atomic bomb as it strikes another object at high velocity. The impact of an object only a few kilometers across (smaller than many known asteroids and comets) can release more energy in seconds than the whole Earth releases (through volcanism, earthquakes, tectonic processes, and heat flow) in hundreds or thousands of years.

More About Extraterrestrial Objects in the Solar System

Thousands, possibly millions, of objects move throughout the solar system, orbiting the Sun. They range from microscopic dust particles to objects tens of kilometers across. Each object moves in its own orbit. We don't know how often they have hit the Earth in the past.

More About Impact Velocity

The minimum impact velocity for collisions with Earth is 11.2 km/s. This is equal to the escape velocity for an object launched into space from Earth's surface.

More About the Sizes of Craters

Objects of less than half a kilometer in diameter can make craters 10 km in diameter.

More About Crater Shapes

Nearly all impact events result in circular craters. In rare cases where the angle of impact was very low (0-10 degrees from the plane of the horizon), craters can be ovoid in shape.

More About Finding Impact Craters on the Ground

When looking for impact craters in satellite images, first pay attention to circular features in topography or bedrock geology. Look for lakes, rings of hills, or isolated circular areas.

On the ground, look for changes in the physical properties of the rocks in and around impact structures. Fractured rock is less dense than unaltered target rock around the structure. Also look ejecta and shocked rock fragments on the original ground surface outside the crater, and for fragments of the meteorite.

Landsat 7 Educational Activity
Finding Impact Craters with Landsat

Date: ______________________

Student Name: __________________________________ Class Period: _________________

Student Worksheet for Step 4:
Describing Satellite Images of Possible Impact Craters

Part I. Consider what effects an impact event might have, and **describe those effects below**. Though you are working in groups for this step of the activity, each student must complete this worksheet.

A. The object itself: Would you expect to see any evidence of the object itself in a satellite image? What evidence might you find?

____

____

B. Shape of the land: What kinds of changes would that impact make to the shape of the land where it hit, and all around?

____

____

C. Effects of Time: What kinds of changes will occur to the impact site over time? Remember that some changes are fast, and some are slow.

____

____

D. What else might you see in these satellite images that could help you learn about an impact crater?

____

____

____

Part II. As a group, study all of the satellite images. Below are their fake names (to use until you've identified them yourselves as impact craters or something else):

AOR
Latitude: N 19° 6'
Longitude: E 19° 15'
Size: 12.6 km in diameter

ELG
Latitude: N 67° 30'
Longitude: E 172° 5'
Size: 18 km in diameter

HGH
Latitude: N 75° 22'
Longitude: W 89° 41'
Size: 20 km in diameter

MAN
Latitude: N 51° 23'
Longitude: W 68° 42'
Size: 72 km in diameter

MSH
Latitude: N 46° 16'
Longitude: W 122° 12'
Size: several km in diameter

RCH
Latitude: 21°04'N
Longitude: 11°22'W
Size: 38 km in diameter

SCH
Latitude: N 37deg 20' 36.1"
Longitude: W 116deg 33' 59.9"
Size: About 300 m in diameter

You need to know that…

❖ All of these satellite images show the Earth's land surface, not another planet's surface, and not the Earth's atmosphere. No hurricanes or tornadoes appear in these images.

❖ The colors in these images are false colors. White isn't always snow; lakes often appear black; vegetation is sometimes red.

❖ All of these landforms are large. One is 300 m in diameter, and the others are 1 km in diameter or larger. Most of them 10-90 km in diameter.

❖ Aliens from other parts of the universe had nothing to do with creating the landforms in these images.

❖ If you see a letter or a face, it's just an accident of nature.

❖ People sometimes make large craters with explosives or large mining equipment.

❖ Multiple Impacts: Sometimes impacts come in twos or threes. It's rare, but it can happen when a comet or asteroid breaks into a couple of large pieces just before it strikes the Earth.

Part III. As a group, now choose two of the images you find most interesting, and prepare to describe them to the class as directed by your teacher.

A. Circle the name or names of the one or two landform(s) your group has chosen to describe for the class. Write next to it if you think it is an impact crater or some other kind of landform.

AOR ELG HGH MAN MSH RCH SCH

B. What evidence do you see in the satellite image that your landform is or is not an impact crater? Describe it here:

____

____

____

Come to agreement as a group about whether or not the image you've chosen is or is not an impact crater, and why.

Teacher Reference for Step 5:
The Landforms Identified

Aorounga
Impact Crater? Yes
Latitude: N 19° 6'
Longitude: E 19° 15'
Age: 345 million years
Size: 12.6 km in diameter
Location: Sahara Desert of northern Chad, Africa
Kind of Image: Spaceborne Imaging Radar-C/X-Band Synthetic Aperture Radar (SIR-C/X-SAR)
Description: An object less than 1 kilometer wide made this crater 7-10 miles wide. The original crater was buried by sediments, which were then partially eroded to reveal the current ring-like appearance. The dark streaks are deposits of windblown sand that migrate along valleys cut by thousands of years of wind erosion. The dark band in the upper right of the image is a portion of a proposed second crater. Scientists are using radar images to investigate the possibility that Aorounga is one of a string of impact craters formed by multiple impacts.

20,000-30,000 years ago, the area that is now the Sahara Desert was a wetland. Different kinds of forces were shaping this crater then.

360 million years ago, the Earth was undergoing a period of mass biological extinction. By way of comparison, the impact that scientists believed wiped out the dinosaurs 65 million years ago involved an asteroid or comet 10 times larger than the one that broke up to form the craters in Chad.

El'gygytgyn
Impact Crater? Yes
Latitude: N 67° 30'
Longitude: E 172° 5'
Age: 3 - 4 million years
Size: 18 km in diameter
Location: Northeastern Siberia
Kind of Image: Landsat 7
Description: This impact crater has been filled in by a lake.

Haughton
Impact Crater? Yes
Latitude: N 75° 22'
Longitude: W 89° 41'
Age: 23 million years
Size: 20 km in diameter
Location: Devon Island, Nunavut, in the Canadian high Arctic
Kind of Image: NASA's Landsat 7
Description: Although Haughton Crater has undergone substantial erosion, many of its surviving geologic features are exceptionally well preserved. The good state of preservation is due mostly to the crater's geographic setting. Erosion in the polar desert of the high Arctic is particularly sluggish due to the low amount of liquid water and the presence of continuous permafrost. The absence of any substantial vegetation cover also limits the weathering of surface materials, while it optimizes the site's exposure for geologic surveys from the ground and by remote sensing.
The impact event punched through the entire stack of Paleozoic sediments present at the time and excavated material from a depth of over 1.7 km, biting into the gneissic basement.

Manicougan
Impact Crater? Yes
Latitude: N 51° 23'

Longitude: W 68° 42'
Age: 214 million years
Size: 72 km in diameter now; 100 km in diameter when created
Location: northern Quebec, Canada
Kind of Image: NASA's Multi-angle Imaging Spectroradiometer (MISR)
Description: Scientists have proposed that impact of an asteroid of about 5 km in diameter created this crater, which was originally about 100 km in diameter. The initial crater rim has disappeared. A broad central uplift persists. Construction of a hydroelectric dam downstream from the crater allowed water to fill the surrounding depression, creating a lake that forms a ring around the central part.

The Manicougan crater is composed of large pieces of rock embedded in finer grained material rock ("impact-brecciated" rock). Geologists have estimated the crater's age by studying the ratios of various radioactive elements in the rock. The lake is bounded by erosion-resistant metamorphic and igneous rocks, and shock metamorphic effects are abundant in the target rocks of the crater floor.

The Manicougan impact event occurred toward the end of the Triassic period. At that time the Earth experienced a mass extinction event involving the loss of roughly 60 percent of all species. Some scientists believe the impact may have been responsible for this mass extinction.

<u>Mount St. Helens</u>
Impact Crater? No. Mount St. Helen's is a volcano.
Latitude: N 46° 16'
Longitude: W 122° 12'
Age: probably less than 1 million years
Size: Several km in diameter
Location: South central part of the State of Washington, northwestern United States
Kind of Image: NASA's Landsat 7

<u>Richat</u>
Impact Crater? No. Richat is a product of erosion.
Latitude: N 21°04'
Longitude: W 11°22'
Age: Modern age
Size: 38 km in diameter
Location: Central Mauritania, northwest Africa
Kind of Image: NASA photograph taken by astronaut on the Space Shuttle
Description: Richat is a depression or pit about 100 m deep, in which there is a dome of rock. The rock is actually different kinds of rock in layers, several hundred million years old. Some kinds of rock erode faster than others. Made of different materials, the layers of rock have eroded at different rates, creating a series of concentric ridges. Fields of sand surround Richat and are encroaching into the southern part of the structure.

Researchers once thought Richat was an impact crater. But its flat middle and lack of shock-altered rock indicate otherwise. A volcanic eruption couldn't have formed it, because there's no dome of igneous or volcanic rock. Why Richat is nearly circular, nobody knows.

<u>Schooner</u>
Impact Crater? No, Schooner is manmade.
Latitude: N 37deg 20' 36.1"
Longitude: W 116deg 33' 59.9"
Age: 20th century
Size: About 300 m in diameter
Location: Nevada, U.S.
Kind of Image: IKONOS (privately-owned satellite); 1-meter resolution
Description: Nuclear testing resulted in the Schooner crater.

Due Date: _________________

Student Name: _______________________________________ Class: ________________

Student Worksheet for Step 6: Questions You Would Ask on a Field Expedition to a Possible Impact Crater

Identifying what might be an impact crater in a satellite image is only the first step in identifying it with 100 percent certainty. That requires people making a field expedition to gather and study evidence at the site itself.

Field expeditions cost money. Getting money nearly always requires writing excellent grant proposals. You have to prove you understand the science and know what you're doing before people will give you the money to do it.

Your task is to write a series of questions you would use to guide a field expedition to determine whether or not a given landform was an impact crater.

You will do well on this learning assessment if you:

– Show evidence that you have a full and complete understanding of how an impact event can shape the land, soil, and surrounding rocks, as well as the atmosphere and living things;
– Use terminology accurately;
– Explain your ideas in ways that makes sense;
– Use complete sentences.

Student Learning Assessment Rubric

LEVEL 4

There is evidence in this response that the student, using analysis, has a full and complete understanding of how impact events have shaped the land, atmosphere, and living things.

- The response synthesizes information to provide a complete description of the known effects of an impact event on the Earth system.
- Ideas are well integrated.
- The response uses accurate terminology to explain scientific principles.

LEVEL 3

There is evidence in this response that the student, using analysis, has a good understanding of how impact events have shaped the land, atmosphere, and living things.

- The response synthesizes information to provide a complete description of the known effects of an impact event on the Earth system.
- Ideas are reasonably well integrated.
- The response uses mostly accurate terminology to explain scientific principles.

LEVEL 2

There is evidence in this response that the student has a basic understanding of how impact events have shaped the land, atmosphere, and living things.

- The response provides descriptions of some known effects of an impact event on the Earth system.
- Ideas are reasonably well integrated.
- The response uses limited accurate terminology to explain scientific principles.

LEVEL 1

There is evidence in this response that the student has limited understanding of how impact events have shaped the land, atmosphere, and living things.

- The response provides partial descriptions of one or two effects of an impact event on the Earth system.
- Ideas are not well integrated.
- The response makes little or no use of accurate terminology to explain scientific principles.

LEVEL 0

There is evidence that the student has no understanding of how impact events have shaped the land, atmosphere, and living things.
The response is completely incorrect or irrelevant, or there is no response.

Extensions

1. Few Craters on the Earth.
   Craters cover the Moon's surface; we can see them easily with a telescope. Why do we find few craters on Earth, and why is it so hard to find them?

   ____

   ____

2. Craters in the Sea.
   Only a handful of impact craters have ever been discovered under the sea. One reason is that the sea floor is harder to get to and to study than places on land. There is another reason. What is it?

   ____

   ____

3. Craters Around the Globe.
   Visit a world map of impact craters at: http://gdcinfo.agg.emr.ca/crater/world_craters_e.html
   Have more impact craters been discovered in some places than in others? Where are these "clusters" of craters? Why are they where they are and not somewhere else?

   ____

   ____

4. Impact on Jupiter.
   Jupiter was hit by fragments of an object designated Comet P/Shoemaker-Levy 9 in 1994. [http://www.jpl.nasa.gov/sl9/] No craters were made by this impact. Why not?

   ____

   ____

5. Impacts Elsewhere in the Solar System.
   Would you expect to find impact craters on solid bodies in the rest of the solar system? Why or why not?

   ____

   ____